THE AGE OF THE EARTH FROM THE POINT OF VIEW OF ASTRONOMY.

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(*Read April 22, 1922.*)

Astronomical evolution is considered under three heads: First, that method of observation in which it is assumed that all stages in the process are visible in the sky and so can be traced step by step. Second, physical theory, based on well-known laws such as those of gravitation, heat, etc. Third, pure speculation. When we attempt to apply these methods to the solar system, we find a complete absence of any observational evidence from the first point of view, because we have no stellar systems sufficiently near for us to detect planets if such exist. Thus evolution in the solar system is mainly a mixture of physical theory and speculation.

All theories of evolution use the idea of contraction under gravitation, which in general causes a gain of heat and of angular velocity. The chief differences between the theories consist in the forms of matter which are assumed to come into existence under the operation of the process of contraction. Laplace imagined that a planetary nebula contracted and in the course of the process left behind rings of matter which later condensed into planets. Roche showed that under certain conditions matter will be thrown off along the equator. G. H. Darwin and Poincaré developed the processes of fission from which it was hoped that planetary bodies might be shown to have developed through successive divisions of the central body. Later workers at the theory, and particularly Jeans, have proved that this hypothesis is very improbable for planetary evolution on account of the fact that in this process of division the masses should be of the same order of magnitude and not, as in the case of the planets, of very different orders of magnitude. It has, however, been applied with considerable success to the evolution of close double stars. Finally there are the tidal hypotheses in which the matter is supposed

to have been drawn off by the close approach of some second body which later moved away. Each of these hypotheses has many objections. But it may be stated that from these points of view we can learn nothing definite or even approximate about the age of the earth.

Another method of approach is through observation of the present condition of the bodies in the solar system. For evidence we have eight major planets, but it is very doubtful whether from so small a number we can deduce any results of value. In fact, it is now well known that differences in mass may produce very different consequences in the history of bodies. Thus arguments drawn from the Moon, Mars, Venus, or the other planets have never inspired very much confidence.

Still another method is a consideration of the present condition of the earth combined with the theory of contraction and subsequent loss of heat. Here we are on somewhat firmer ground, since we have many observations which give information concerning the interior condition of the earth. Amongst these may be mentioned the values of the mean density and the surface density, the phenomena of precession, nutation, etc., the measurements of earthquake and seismic waves, and measurements of the rigidity of the earth by various methods, and more particularly by that lately developed at Chicago by Michelson and his colleagues. From these phenomena we know with fair certainty that the earth *behaves* like a solid body which has approximately the rigidity of steel. It is sometimes assumed that this shows that the interior of the earth consists of matter which under surface conditions of pressure would be solid. Unfortunately the argument is doubtful, because we know nothing of the condition of matter under the pressures which it experiences at depths of one hundred miles or more below the surface of the earth. It is, therefore, impossible to argue with any security concerning the temperature conditions in the interior of the earth from these observational data. Lately Jeffreys has shown that under almost any theory of evolution the earth must at one time have been sufficiently hot so that all its materials were in a liquid state, understanding by this latter phrase, a state liquid under surface conditions of pressure.

Thus the astronomical evidence which can be furnished as to the

age of the earth is practically nil and one must turn to methods outside the range of the astronomer's work.

A further difficulty may be mentioned. Evidence is accumulating that there is widely extended diffuse matter in space, some of which is visible and some of which is only evident on account of the obscuration of light which it causes. It therefore seems highly probable that the solar system in the course of several hundred million years may have passed through one or several such clouds. These would have effects, which from theory are well known, such as diminishing the mean distances of the planets from the sun, the circularization of their orbits, possible changes in the total angular momentum of the system, and other effects such as the possible formation of comets and the production of glacial and interglacial periods. At present, however, the consequences of this hypothesis are still in the range of speculation and need to be worked out in considerable detail before any arguments can be built on it. It may, however, be stated that such a hypothesis would have the general tendency of increasing the age of the earth as estimated from other sources.